MOLTEN

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Response to Request for Comments on Credits for Clean Hydrogen and Clean Fuel Production Notice 2022-58

Summary

There should be an incentive to reward clean hydrogen producers for purchasing low lifecycle greenhouse gas emissions Certified Natural Gas or renewable natural gas over “normal” natural gas with higher emissions intensity when using methane pyrolysis and steam methane reforming with carbon capture and storage for hydrogen production. The hydrogen PTC and ITC vehicles are an excellent method of encouraging increased monitoring and verification of upstream methane emission intensity and promoting purchasing of low-emission methane.

Establishing average methane intensities for US natural gas production or production by basin is a convenient accounting practice, but it does not consider the fact that methane emissions are highly time variable and vary widely from producer to producer and even well to well. This does not encourage natural gas producers or processors to reduce emissions and does not encourage consumers of natural gas to choose producers who have demonstrated low methane emissions intensities.

Certified Natural Gas or Responsibly Sourced Gas with upstream emissions intensity verified by independent third parties should be included as a potential source of natural gas feedstock for hydrogen production and included in the GREET model for upstream natural gas lifecycle greenhouse gas emission intensity for the accounting purposes of the Inflation Reduction Act hydrogen production tax credit under section 45V and investment tax credit under section 48.

Furthermore, blending of renewable natural gas (RNG) from dairy farms, waste-water treatment plants, and landfills with natural gas and certified natural gas should be included in the GREET model for methane feedstocks for hydrogen production via methane pyrolysis or steam methane reforming.

Methane pyrolysis, when using certified low-emission intensity natural gas and 100% renewable energy, has the potential to achieve well-to-gate lifecycle greenhouse gas emissions below 0.45 kg CO_2e/kg H_2. When using RNG or blends of RNG and certified natural gas,

methane pyrolysis has the potential to achieve carbon-neutral or carbon-negative clean hydrogen production.

About Molten Industries

Molten Industries is an Oakland, California-based startup with a goal to produce the lowest-cost, cleanest hydrogen on the planet. Molten's simple process cracks methane at white hot temperatures into hydrogen and solid carbon using renewable electricity, a technology called methane pyrolysis. High temperatures are achieved using electrical resistive heating, similar to a toaster oven. The process creates no carbon dioxide, instead producing hydrogen and a valuable solid carbon by-product that can be used in concrete, paints, plastics, and tires. *Molten's methane pyrolysis process, when using certified low-emissions natural gas, has the potential to achieve well-to-gate lifecycle greenhouse gas emissions below 0.45 kg CO_2e/kg H_2.*

While clean methods of hydrogen production exist – like water electrolysis – they rely on large amounts of renewable wind and solar energy. Methane pyrolysis has the potential to use five times less energy than water electrolysis per kilogram of hydrogen produced and can use existing natural gas networks to produce clean hydrogen where it is consumed.

Molten's methane feedstock is responsibly procured from certified low-emissions natural gas sources[1,2] and waste streams such as dairy farms, waste-water treatment plants, and landfills. This leads to hydrogen and carbon with well-to-gate lifecycle greenhouse gas emissions below 0.45 kg CO_2e/kg H_2. When using renewable natural gas (RNG) from waste methane sources, Molten's process has the potential to achieve carbon negative well-to-gate lifecycle emissions, by sequestering carbon from methane as a solid. This can be achieved with a pure RNG feedstock or a blended feedstock of a small amount of RNG with natural gas.

Certified Low-Emission Natural Gas as a Feedstock for Clean Hydrogen Production

Certified Natural Gas or Responsibly Sourced Gas with upstream emissions intensity verified by independent third parties should be included as a potential source of natural gas feedstock for hydrogen production and included in the GREET model for upstream natural gas lifecycle greenhouse gas emission intensity for the accounting purposes of the Inflation Reduction Act hydrogen production tax credit under section 45V and investment tax credit under section 48.

Lifecycle greenhouse gas emissions of clean hydrogen produced from both methane pyrolysis and steam methane reforming with carbon capture are highly dependent on upstream

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[1] https://miq.org
[2] https://www.projectcanary.com

methane emissions from leaks that occur during natural gas production, gathering and boosting, processing, transmission, and distribution.

Figure 1 plots the lifecycle greenhouse gas emissions of an ideal methane pyrolysis process with zero process CO_2 emissions versus upstream methane leakage rate, showing that to achieve lifecycle emissions <0.45 kg CO_2e/kg H_2, the upstream methane leakage rate must be below 0.4% (without RNG blending).

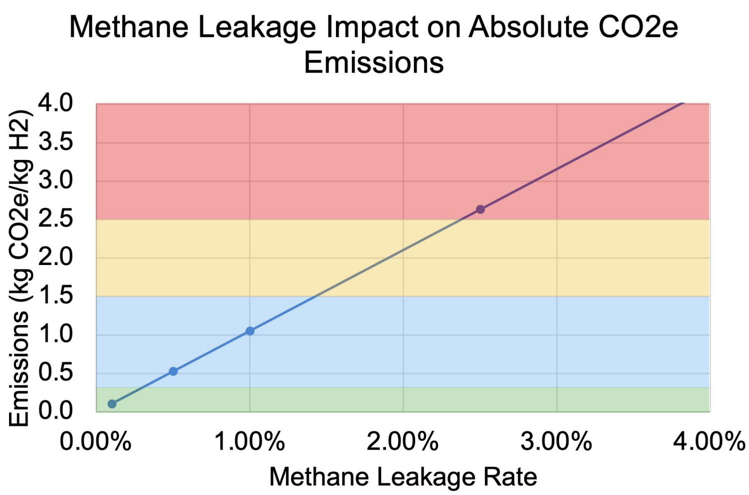

Figure 1: Plot of lifecycle greenhouse gas emissions of methane pyrolysis versus upstream methane leakage rate assuming a carbon neutral methane pyrolysis process. Red, orange, blue, and green shaded regions represent the emissions ranges for the 20%, 25%, 33.4%, and 100% hydrogen production tax credit, respectively, as specified in section 45V of the Inflation Reduction Act. Methane emission intensity assumed at 100 year global warming potential of 25.[3]

This 0.4% methane emissions number compares favorably with targets for methane emissions laid out in the Inflation Reduction Act in Section 136, which levies a $900/ton fee on methane emissions. These fees apply to emissions above 0.20% of natural gas sent to sale from petroleum and natural gas production facilities, emissions above 0.05% for nonproduction facilities, and emissions above 0.11% for natural gas transmission facilities. Therefore, if methane pyrolysis for hydrogen production uses natural gas feedstock that complies with the methane emissions targets above and is only sent through one of each of the facilities above before use, it would be limited to a maximum of 0.36% upstream methane emission rate.

However, recent analyses suggest that mean methane leakage rates from the production segment alone in the United States are 1.3%-1.4%.[4,5] Furthermore, reports indicate that the EPA's Greenhouse Gas Inventory is underestimating the true methane emissions from the oil and gas sector, which can **vary widely from producer to producer, basin to basin, and even**

[3] https://www.epa.gov/ghgemissions/overview-greenhouse-gases
[4] https://www.nature.com/articles/s41467-021-25017-4
[5] https://www.science.org/doi/10.1126/science.aar7204

well to well.[6] There is a wide gap between the targeted methane leakage rates that would allow for <0.45 kg CO_2e/kg H_2 intensity hydrogen production and the actual mean leakage rates for natural gas today in the United States.

Ideally, the methane emissions fee in the IRA would solve this discrepancy, but a series of loopholes and exemptions offer the potential for many methane emitters to continue emitting methane while selling natural gas on the market. "This is a bowl of spaghetti. There are so many exemptions, exclusions, definitions that you really have to keep track of all of them. With all of these criss-crossing exemptions and mandates… it's hard to tell where it's going to come down, but if there is a methane fee applied it won't last more than a year or two." - Dr. Robert Kleinberg, Senior Research Scholar, Columbia University.[7]

To achieve very low methane leakage rates on feedstock for hydrogen production from methane pyrolysis or steam methane reforming with carbon capture facilities, hydrogen production facilities have the option of procuring Certified Natural Gas or Responsibly Sourced Gas (RSG). Third party verification organizations such as MiQ (https://miq.org) and Project Canary (https://www.projectcanary.com) provide continuous upstream monitoring along the entire gas value chain and create certificates for natural gas that is <0.05% to <0.2% in methane intensity, depending on the certificate level.

Preventing methane emissions in the upstream oil and gas industry is a very attainable goal at reasonable cost. The IEA estimates that 70% of the United States methane emissions from oil and gas operations can be eliminated for an annualized net cost of $1.7 billion, representing a cost of $176/ton methane, much lower than the fees imposed in the Inflation Reduction Act.[8] Amortizing this cost across the existing annual US natural gas production would represent a price increase of $0.05/MMBtu, or roughly a 1% price increase at the current Henry Hub spot price of $5/MMBtu.[9]

There should be an incentive to reward clean hydrogen producers using methane pyrolysis and steam methane reforming with carbon capture and storage to purchase low lifecycle greenhouse gas emissions Certified Natural Gas over "normal" natural gas with higher emissions intensity. The hydrogen PTC and ITC vehicles are an excellent method of encouraging increased monitoring and verification of upstream methane emission intensity and promoting purchasing of low-emission methane.

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6 https://science.house.gov/news/press-releases/science-committee-majority-staff-report-finds-oil-and-gas-sector-fails-to-quantify-and-address-super-emitting-methane-leaks

7 https://ngi.stanford.edu/events/meta-seminars/robert-kleinberg-newly-enacted-climate-legislation-inflation-reduction-act

8 https://www.iea.org/data-and-statistics/data-tools/methane-tracker-data-explorer

9 https://www.eia.gov/dnav/ng/hist/rngwhhdm.htm

Establishing average methane intensities for US natural gas production or production by basin is a convenient accounting practice, but it does not consider the fact that methane emissions are highly time variable and vary widely from producer to producer and even well to well. This does not encourage natural gas producers or processors to reduce emissions and does not encourage consumers of natural gas to choose producers who have demonstrated low methane emissions intensities.

Enabling clean hydrogen producers to use Certified Natural Gas or Responsibly Sourced Gas with upstream emissions intensity verified by independent third parties in the lifecycle greenhouse gas emission intensity analysis of their hydrogen production processes would encourage consumption of low-emission methane. Certified low-emission intensity natural gas should be included as a potential source of natural gas feedstock for hydrogen production in the GREET model.

Renewable Natural Gas Blending as a Feedstock for Clean Hydrogen Production

Blending of renewable natural gas (RNG) from dairy farms, waste-water treatment plants, and landfills with natural gas and certified natural gas should be included in the GREET model for methane feedstocks for hydrogen production via methane pyrolysis or steam methane reforming.

Methane pyrolysis has the potential to produce carbon-negative hydrogen when used with renewable natural gas (see **Figure 2**).

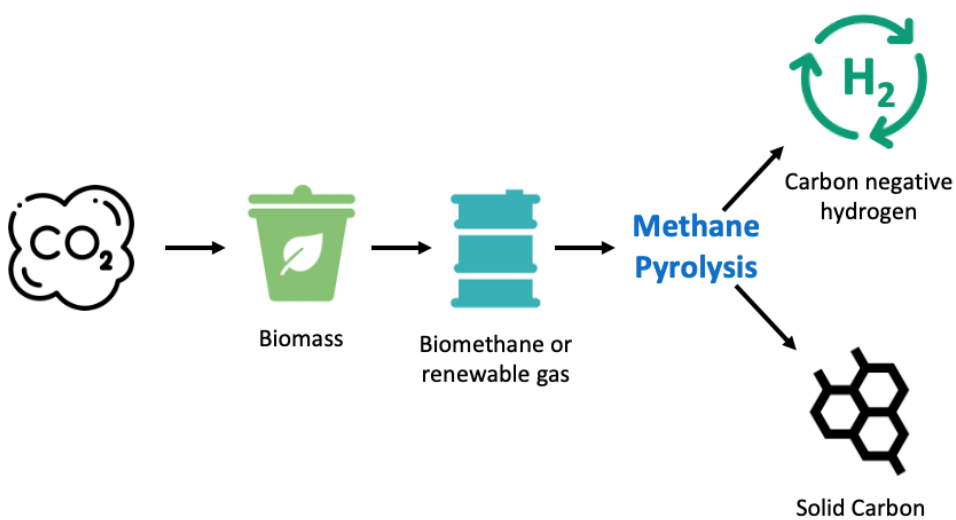

Figure 2: Diagram of production of carbon negative hydrogen using methane pyrolysis with biomethane or renewable natural gas (RNG), showing how CO_2 from the sky can be sequestered in solid carbon.

Furthermore, upon mixing a small fraction of RNG with natural gas, methane pyrolysis producers of clean hydrogen can reduce their respective carbon footprints, offsetting upstream methane emissions (see **Figure 3**). This is an exciting route to producing low-cost, carbon-negative hydrogen. Blending RNG with natural gas makes also sense from a scalable supply perspective, as RNG supply in the United States will have difficulty replacing natural gas entirely given limited supply.

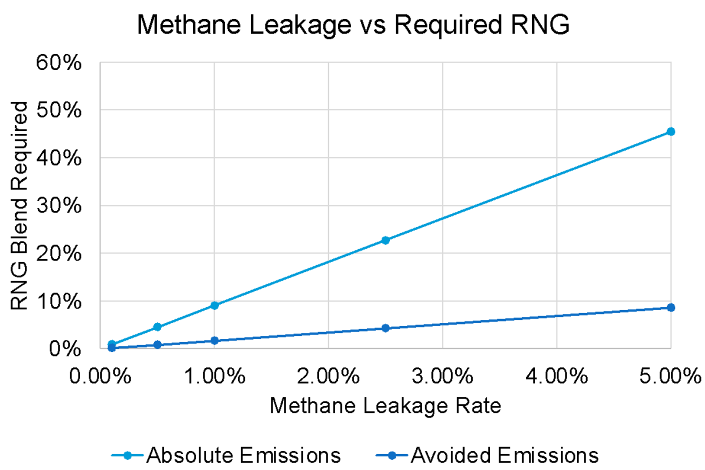

Figure 3: RNG blending required for an ideal methane pyrolysis plant to achieve carbon-neutral hydrogen production from well-to-gate assuming upstream methane leakage rates of both RNG and natural gas of up to 5%. Absolute emissions blending carbon intensity is determined with an absolute carbon accounting factor, where 1 mole of carbon in CH_4 from RNG is equivalent to 1 mole of carbon in CO_2 sequestered. Avoided emissions blending carbon intensity is determined from avoided dairy methane emissions using the California LCFS framework.[10]

The impact of RNG blending in offsetting lifecycle greenhouse gas emissions depends highly on whether the framework used to account for emissions of the RNG itself is based on absolute emissions or avoided emissions. Absolute emissions blending carbon intensity is determined with an absolute carbon accounting factor, where 1 mole of carbon in CH_4 from RNG is equivalent to 1 mole of carbon in CO_2 sequestered. Avoided emissions blending carbon intensity is determined from avoided methane emissions, like the California LCFS framework. Some types of RNG, such as dairy biomethane, are very carbon negative under the current California LCFS framework of avoided emissions, achieving CI scores of up to -600 gCO_2e/MJ.[11]

Blending of RNG with certified natural gas or “normal” natural gas should be considered as a feedstock for clean hydrogen production and included in the GREET model for lifecycle greenhouse gas emissions intensity of hydrogen produced with methane pyrolysis or steam methane reforming with carbon capture and storage.

[10] https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities
[11] https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities